FIRST DRAFT REPORT

UNION LAKE EUTROPHICATION STUDY: LABORATORY FLASK EXPERIMENT

Performed for the Landis Sewerage Authority by
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Summary

A laboratory experiment was conducted in which native algae were allowed to grow in flasks of water from Union Lake, Millville, NJ, with added phosphate levels simulating the projected effects of a new sewage treatment facility upon that lake. Anionic arsenic was removed from the water in some of the flasks but not others in order to detect any possible algal growth limitation due to the toxic affects of that element. No toxic effects were detected at 6.2 ppb As as compared with 0.3 ppb. Blooms of filamentous bluegreen algae occurred in all flasks receiving the projected low flow concentration of phosphorus (high P conc.) of 0.44 mgP/l in as little as 5 days. Chlorophyll a concentrations approaching the maximum theoretical value dictated by phosphorus concentration, and a close correlation between chl a and initial phosphate in flasks strongly suggest that available phosphorus is the limiting factor for algal growth and consequent eutrophication in Union Lake water, at least under the conditions of the experiment. The rapidity of development of the bloom in some flasks also suggest that such blooms could also develop in the lake despite its short hydraulic residence time.

Introduction

The overall purpose of the Union Lake eutrophication study is to determine the necessity or lack thereof for the funding by US EPA of construction of an advanced treatment (nutrient control) facility as part of the Landis Sewerage Authority's 8.2 MGD secondary treatment plant now under construction. More specifically, will discharge to the Maurice River drainage system of this treatment plant without the the AT facility create a eutrophication problem downstream of the plant in Union Lake? The study is designed to approach this question by means of laboratory and field eutrophication experiments and by means of computer simulation of water quality changes. This report deals with preliminary results obtained in the laboratory experiments performed thus far.

While previous work has suggested that Union Lake should be considered eutrophic as a result of high phosphorus loading (1), there is also evidence that phosphorus may not be the limiting factor for algal growth, casting some doubt upon the hypothesis that increased phosphorus loading from the new Landis treatment plant would promote algal blooms and further degradation of water quality in Union Lake (2). The factor(s) involved in the limitation of algal growth during the summer of 1973 did not appear to involve nutrient concentrations, the availability of light, or the shortness of the residence time of water in the lake (3). The author of the present study hypothesizes that the limiting factor for algal growth was in fact arsenic toxicity resulting from waste release from a local pesticide manufacturer. The waste releases ceased during the 1970's, but USGS data for the Maurice River at Norma, NJ indicate that some elevation of arsenic concentration in the water has persisted, probably as a result of leaching from contaminated sediments, up until October, 1986, the date of the last available data.

What is most significant is that the total dissolved arsenic concentrations in that USGS record have been declining from the range of 200 - 300 ug As / l in 1979 - 1980 to 50 - 100 ug As / l in 1986. If this trend continues, this concentration will be reduced still further within the next few years. The process will be accelerated if the Maurice River and Union Lake become the site of a Superfund cleanup effort. If arsenic was the limiting factor for algal growth previously, the reduction of its prevalence may leave phosphorus as the limiting factor in the near future, opening the possibility of considerable degradation of water quality in response to increased phosphorus loading. The 1986 arsenic concentrations are already approaching the lowest known toxic levels for algae recorded in the literature (4). For this reason the present investigation is dealing both with the effects of nutrients and those of arsenic concentrations upon algal growth.

The flask experiment was conducted in anticipation of the *in situ* experiment to be conducted in the lake itself. The objectives of the flask experiment were twofold:

1. To determine whether phosphorus addition alone was sufficient to induce a phytoplankton bloom in Union Lake water under ideal conditions, and

2. To determine the efficacy of using anion exchange resins to remove arsenic from Union Lake water, and consequently to promote algal blooms.

Methods and Materials

Water for this experiment was collected at two sites. Union Lake water was collected from an eddy at the base of a sandbag dam in the upper part of the present lake near the site of the original eighteenth century dam. Maurice River water was collected at the Garden Street crossing, upstream of the area contaminated with arsenic. Samples were kept on ice during transport and refrigerated at 4° C until use.

Experimental pretreatment of the water to remove arsenic was accomplished with Rohm and Haas Amberlite® anion exchange resins IRA 900 and IRA 904. Approximately 50 ml of a slurry of resin in distilled water was added to every 6 liters of lake water and stirred for 45 min. The resin was then allow to settle and the lake water decanted for use in experiments. Since resin treatment lowered the pH of the water, sodium bicarbonate was added to all water used in order to bring the pH to the range of 7.0 to 7.3.

Chemical analyses performed on untreated and treated lake water and Maurice River water included orthophosphate by the molybdate method (5), nitrate + nitrite by Hach kit, ammonia by direct Nesslerization (6), and total dissolved arsenic by graphite furnace atomic absorption spectrophotometry (AA) (6). The extent and nature of algal blooms was assessed by direct visual and microscopic inspection and where possible, by chlorophyll a determinations (7).

Concentrations of orthophosphate to be used in experiments were determined by estimating the effect of the 8.2 MGD plant on the nutrient concentrations in Union Lake. Using the USGS data for low flow during 1973-74 of 3.23 m^3/sec at the Sharp Street dam, a treatment plant discharge of 0.359 m^3/sec (= 8.2 MGD), an estimate of 1.134 kg phosphorus output per capita (1) for 82,000 people, and a background phosphate concentration of 0.03 mg / l, this author estimates a low flow concentration of 0.437 mg PO_4-P / l. At the 1973-4 high flow of 14.05 m^3/sec, phosphate is estimated to be 0.132 mg P / l. For the purposes of this experiment, inorganic nitrogen concentrations were initially adjusted to the same level as was found in the untreated Union Lake water. No provision was made for increased nitrogen concentrations to simulate the discharge of the new treatment plant. Since the anion exchange resins removed some nitrite-nitrate as well as arsenite-arsenate from treated water, nitrate additions were made to treated water in order to restore the original untreated water concentrations of this nutrient. Phosphate additions to resin-treated water to achieve desired final concentrations also took into account phosphate removal by the resin as well as the desired increase in phosphate. Potassium nitrate and dibasic potassium phosphate were used for these additions. Ammonia concentrations were unaffected by the resin, and hence not altered.

The experiment consisted of fourteen 1 liter aliquots of water in 1 liter glass Ehrlenmeyer flasks. Twelve flasks contained Union Lake water, four each of untreated water, water treated with resin IRA 900, and water treated with resin IRA 904. Within each group of four, one flask had an initial phosphate concentration of 0.03 mg P / l (ambient), one of 0.06 mg/l (twice ambient), one of 0.132 mg/l (new plant-high flow), and one of 0.437 mg/l (new plant-low flow). The remaining two flasks contained Maurice River water with 0.437 mg PO_4-P / l (new plant-low flow). A small quantity of Maurice River sediment from the Garden Street crossing site was added to each flask in order to insure an adequate supply of native algae.

Flasks were illuminated 24 hours a day by three 150 W incandescent flood lamps at distances ranging from 50 to 70 cm from each flask. This provided a calculated light intensity of 217 $\pm$ 26 W/m^2 (mean $\pm$ SD), which approximates average spring and fall illumination intensities at 40° N latitude (7). Union Lake is at 39° 20' N. Water temperatures in the flasks varied from 30 to 35° C. To supply carbon dioxide and prevent carbon limitation of photosynthesis, aeration was provided to each flask through a standard aquarium airstone for 5 hours per day, two and a half hours in the morning, and two and a half at night. While the author recognizes that these experimental conditions entail more hours of illumination, higher temperatures, and higher pH than would be experienced in Union Lake itself, the experiment was designed to "push" a bloom quickly to see if there was some other limiting factor besides phosphorus concentration.

Unaided visual observations of the flasks were made daily, with pH measurements and microscopic examinations being made irregularly. Chlorophyll a was assessed for some of the flasks on two occasions, once on the seventh day, and once on the thirteenth day of the experiment. When samples of 250 to 500 ml were drawn and filtered for cholorphyll a determination, the filtered water was returned to the original experimental flask along with the unfiltered portion of the water, and the flask was placed back into the experiment.

Results and Discussion

I. Water Chemistry

The results of the chemical analyses of the untreated and treated water samples prior to nutrient addition presented in table 1.

TABLE 1. NUTRIENTS AND ARSENIC IN WATER SAMPLES

Source	Treatment	[PO_4] (mgP/1)	[NO_3] (mgN/1)	[NH_3] (mgN/1)	[As] (ugAs/1)
Union L.	none	0.033	0.81	0.70	6.2
Union L.	IRA 900	0.016	0.19	0.75	2.1
Union L.	IRA 904	0.028	0.00	0.73	0.3
Maurice R.	none	0.013	0.23	0.31	<0.1

IRA 904 was the most efficient resin for arsenic removal.

The low concentration of arsenic in the untreated Union Lake water was not anticipated. As previously stated, the most recent data indicates values ranging from 50 to 100 ug/1. Whether this particular sample is anomalous or represents a trend or is somehow influenced by the drawdown of the lake in its present state cannot be stated, but for the purposes of this experiment, it is unlikely that such a low concentration of As will affect the results of the untreated group as compared with the treated groups.

The nutrient content of the individual flasks after nutrient addition is indicated in table 2.

TABLE 2. NUTRIENT AND ARSENIC CONCENTRATIONS IN EXPERIMENTAL FLASKS

Flask No.	Treatment	Condition	[PO_4]	[$TN_{inorg.}$]	[As]
U1	none	low flow	0.44	1.51	6.2
U2	none	high flow	0.13	1.51	6.2
U3	none	2X ambient	0.06	1.51	6.2
U4	none	ambient	0.03	1.51	6.2
900-1	IRA 900	low flow	0.44	1.51	2.1
900-2	IRA 900	high flow	0.13	1.51	2.1
900-3	IRA 900	2X ambient	0.06	1.51	2.1
900-4	IRA 900	ambient	0.03	1.51	2.1
904-1	IRA 904	low flow	0.44	1.51	0.3
904-2	IRA 904	high flow	0.13	1.51	0.3
904-3	IRA 904	2X ambient	0.06	1.51	0.3
904-4	IRA 904	ambient	0.03	1.51	0.3

MR1	none	low flow	0.44	1.51	<0.1
MR2	none	high flow	0.44	1.51	<0.1

II. Observations

No obvious changes occurred in the appearance of the flasks during the first three days of the experiment. The pH range of the water in the flasks had risen to 7.5 to 7.9 (from 7.0 to 7.3) by the third day, probably due to photosynthetic withdrawal of carbon dioxide from the water. Microscopic examination of the phytoplankton from the Union Lake water on the first day of the study revealed a mixed flora dominated by the filamentous bluegreen alga *Anabaena* sp. Other algae present included other filamentous cyanophytes (*Oscillatoria* sp. and *Aphanizomenon* sp.), and a variety of diatoms, desmids, (*Scendesmus* sp., *Tabellaria* sp., *Pediastrum* sp., *Staurastrum* sp.) and both solitary and colonial green flagellates.

By the fifth day a turbid green appearance had developed in flask 904-1 Union Lake water with the lowest arsenic and highest phosphate concentration. The algal community consisted entirely of *Anabaena* and green flagellates, and the pH had risen to 9.4. The pH in all other flasks ranged from 8.3 to 8.6. On the sixth day, flask U1, with the highest levels of both arsenic and phosphate, started to become cloudy and green, but its algal flora was still similar to the original mixed community, and its pH still only 8.3. By the seventh day the green color was fading from 904-1, and its pH was back to 8.4. U1 had reached its peak of color, became more heavily dominated by *Anabaena*, and had a pH of 9.1. Fig. 1 presents photographs of these flasks. The fact that these two flasks demonstrated blooms so close in time strongly suggest that arsenic at 6.2 ug/l has little effect on algal growth, particularly the growth of *Anabaena*.

After "thinning" of the bloom as a result of a partial harvest for chlorophyll *a* determination on the seventh day, the bloom in flask U1 remained very green with pH remaining between 9.4 and 9.8 until at least the thirteenth day. The bloom in 904-1, by contrast, continued to decline, losing color, turbidity, and with pH between 8.4 and 8.6.

By the eleventh day flask 900-1 was becoming cloudy and green, but still had a pH of only 8.8, flask MR1 had developed an obvious bluegreen algal mat on the bottom (possibly *Nostoc*), a very deep amber color in the water, and a pH of 9.9. MR2 began to demonstrate a slight darkening in its water color, too. Over the next week, MR2, 900-1, and 900-2 all developed the algal mat and deep amber color as in MR1.

By day 26, all of the flasks that had experienced the low flow (high phosphate) condition: U1, 900-1, 904-1, MR1, and MR2, had demonstrated very visible changes in water quality associated with bluegreen algal growth. Even one of the high flow flasks (900-2) had developed this condition by this time. One had reached this condition after only five days. This finding suggests that Union Lake, with 21 day low flow hydraulic residence time, might experience a significant algal bloom with accompanying water quality degradation the new treatment plant on line. The *in situ* field experiment being conducted at this time in Union Lake will test this hypothesis under more realistic environmental conditions.

III. Chlorophyll a Data

The chlorophyll a concentration of the Union Lake water used in these experiments was initially 16.2 ug/l. Determinations for the two blooming flasks (904-1 and U1) on the seventh day of the experiment yielded 284.6 and 319.8 ug/l, respectively. It is likely that the value for 904-1 was actually higher one or two days earlier, since the color and pH value in that flask were already waning by day 7.

On day 13 chlorophyll a determinations were made for flasks U1, U2, U3, and U4. An attempt was also made to do a determination for MR1, but pigment extraction from the matted algae in that flask proved unsatisfactory. Despite losing half of its algal biomass because of the chl a determination made 6 days earlier, U1 yielded 361.5 ug/l on day 13. Assuming that a 1 ug/l increase in available phosphorus would yield a 1 ug/l increase in chl a (3), 361.5 ug/l is close to the maximum possible concentration for a an initial phosphate concentration of 0.44 mg P / l (440 ug/l). Although though they showed no gross visible signs of algal growth, flasks U2 through U4 also demonstrated a chlorophyll a pattern that was related to their respective initial phosphate concentrations (Fig. 3). The linear least squares regression correlation coefficient for this relationship between initial orthophosphate concentration and chlorophyll a concentration after 13 days for the four untreated flasks is 0.9958.

The proximity of the highest chl a value to the theoretical maximum and the close correlation of chlorophyll a with initial phosphate concentration strongly suggest that available phosphorus is the only limiting factor for algal growth in Union Lake water, at least under the conditions of the flask experiment.

References

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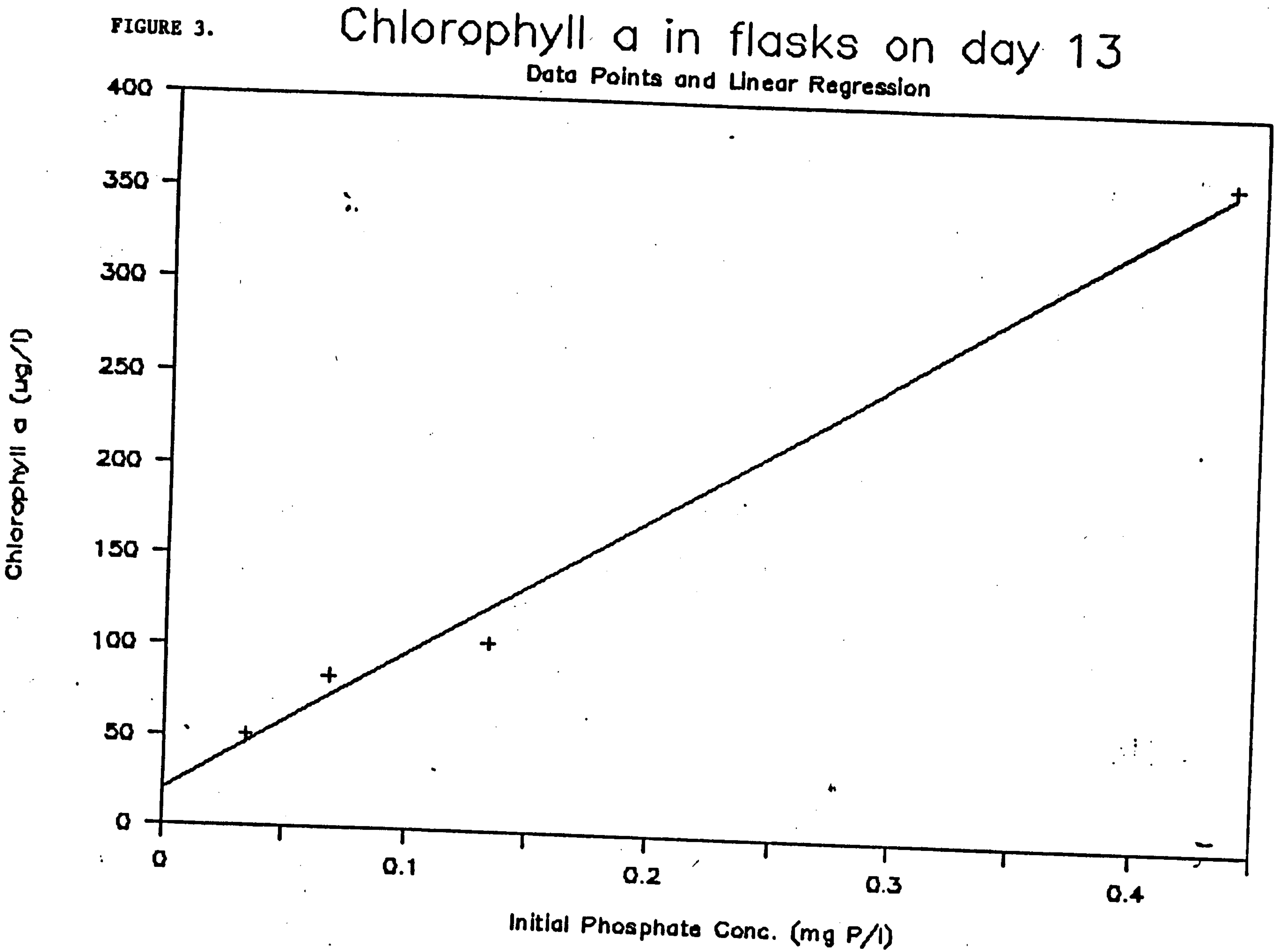
FIGURE 3.


Chlorophyll a in flasks on day 13
Data Points and Linear Regression
400
350
300
250
200
150
100
50
0
Chlorophyll a (ug/l)
0
0.1
0.2
0.3
0.4
Initial Phosphate Conc. (mg P/l)